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THE GEOLOGY OF PHILADELPHIA,

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PROF. H. CARVILL LEWIS.

(A Lecture delivered before the Franklin Institute, January 12, 1882.)

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The formations upon which the city of Philadelphia is built may be divided into two great classes—the superficial formations and the underlying rock strata. The former of these, much the most recent of the two, are for the most part closely connected with the "Great Ice Age" which formed the subject of the lecture given one week ago. A description was then given of the ice-covered area of Pennsylvania, and of the numerous phenomena of glacial action which pertain to that region. The extent and the causes of glaciation were discussed, and an attempt made to arrive at some idea of its age. The great glacier which covered the whole northeastern portion of our continent, and which, as a great sea of ice, flowed in a continuous stream across Labrador, the Laurentian highlands of Canada, the Adirondacks, the Catskills and the Alleghanies, was proved to have finally stopped within sixty miles of our city. At the extreme edge of the glacier it heaped up a terminal moraine, composed of rock fragments brought from more northern regions, which moraine was shown to stretch in a continuous line completely across our State.

Directing our attention now to the rivers which cut through the moraine, it will immediately be evident that, at the time of the melting and retreat of the great glacier, these rivers must have been swollen to great dimensions by the floods which then rushed down them. They constituted the drainage courses for the waters of the melting glacier. Our spring freshets are nothing in comparison to the mighty torrents into which these rivers must have then been converted. These torrents brought down immense masses of loose material made by the glacier, while at the same time they tore up and carried down stream loose rocks all along their beds. When at last the flood subsided there remained as witnesses of its extent the clays, the gravel and the cobblestones which we are about to study in detail. Among the rivers which brought down these deposits were the Delaware, the East branch of the Susquehanna and the Alleghany.

On the other hand, as may be seen by reference to the map of the moraine, the Schuylkill and the west branch of the Susquehanna did not issue from glaciers, their source being south of the moraine. It is now evident, therefore, why there are no drift deposits in the valleys of the last-named rivers, while on the other hand such deposits are of great extent in the river valleys first named.

A small portion of the superficial deposits of that part of the Delaware which lies between Trenton and the sea is due to marine or estuarine action, being more ancient than the deposits of glacial times.

In entering upon an examination of the geological formations of any place, the first step is the construction of a geological map. This we may proceed to do in our city as follows:

THE UPLAND TERRACE.

1. A traveler going from the city upon the Germantown Railroad will notice in the cuttings for new streets between Tenth and Broad streets, and in the railroad cut at New York Junction, numerous exposures of red or yellow gravel, often overlaid by clay. The brickyards in the vicinity of Nicetown expose large beds of brick-clay, containing occasional well-rounded boulders and pebbles. The land so far has been comparatively level, and no rocks have been seen. Just before reaching Wayne Junction, rocks rise upon both sides of the road, the clay and gravel disappear, and a rolling wooded country is entered. A thin covering of light micaceous soil, containing no pebbles or boulders, covers the gneissic rocks from here to Chestnut Hill. There is a great contrast between the two regions.

2. On the Pennsylvania Railroad it will be noticed that, soon after leaving the depot, gravel covers the rocks along the Schuylkill, and as the railroad turns back from the river, a plateau of clay follows. The Centennial grounds lie upon this clay, and boulders are frequent, a good section being exposed near the bridge at Belmont avenue. Upon reaching Fifty-seventh street, opposite Belmont and George's Hill, the hill is entered by a cut, the rocks come to the surface, and the drift is no more seen.

3. Again, on the North Pennsylvania Railroad gravels first appear,

then, on higher ground, clay, and soon after passing Green Lane Station, the rocky uplands, free from drift.

4. So, too, on the West Chester Railroad, gravels and clays cover the ground up to the base of the hill on which Swarthmore College stands.

5. On the other hand, the New York division of the Pennsylvania Railroad and the Philadelphia, Wilmington and Baltimore Railroad, which run parallel with the Delaware river, do not rise out of the region of drift.

Now, connecting by a line the four points mentioned, it will be found to represent a long straight hill, 200 feet or more in height, having a northeast and southwest trend, parallel to the river, and lying at a mean distance from it of about four miles. The speaker has traced it, through Bucks, Philadelphia and Delaware counties, into the State of Delaware, and finds that it uniformly defines the western boundary of the drift. This hill is easily recognized, where uncrossed by creeks, being remarkably straight and of uniform height. It forms the limit of tide-water, and is recognized where it crosses streams by the occurrence of rapids or falls. Being the first hill of importance west of the Delaware, it often commands a fine view, and is a favorite site for residences. The geographical position of this ancient terrace may be more exactly defined in the vicinity of Philadelphia as the hill which crosses Second street pike near Foxchase, and, crossing Tacony creek farther south, runs nearly parallel with it as far as Crescentville; which crosses Green lane and New Second street road near the place of Mr. J. L. Fisher; crosses the North Pennsylvania Railroad above Olney road, and the York road below the Jewish Hospital; which crosses Germantown avenue at the railroad bridge (being here called Negley's Hill), and running along the railroad to beyond Wayne Station, passes back of the Germantown Cricket Ground, past Old Oaks Cemetery, to Falls of Schuylkill. Thence, passing Chamouni, Belmont and George's Hill, it crosses the Pennsylvania Railroad near Hestonville, and Haverford road at Haddington; passes back of the Burd Orphan Asylum into Delaware county, and runs north of Kelleyville, Clifton and Morton to Swarthmore College, and thence, past Village Green, into Delaware.

North of Philadelphia, this hill may be followed through Bucks county, past Somerton, to the Neshaminy creek, when it crosses the Bound Brook Railroad, and then bends back to form the hill back of

Yardleyville. This hill, which is approximately parallel not only to the river, but also to the shore of the Atlantic Ocean and to the line of strike of the Cretaceous formations of New Jersey, forms, as we have seen, the main dividing line between the ancient and the modern formations.

The speaker has called it for convenience the *Upland Terrace.* The strike of the gneiss forming it corresponds closely with the trend of the terrace itself. A boulder-bearing clay rests upon its southeastern slope, at a uniform elevation of 150—180 feet above mean ocean level. While it is true that, as will appear hereafter, there are patches of an ancient gravel on high points back of it, the Upland Terrace nevertheless remains as the most important geological feature in southeastern Pennsylvania.

Between the Upland Terrace and the Delaware, clays and gravels cover the rocks in a continuous sheet except where eroded away in the neighborhood of streams. The amount of their erosion is in some respects a measure of the age of the surface formations. These formations in the vicinity of Philadelphia have undergone very different amounts of erosion, the amount of such erosion increasing as we recede from the Delaware; and this fact offers evidence that the deposits are of different ages; those lying farthest from the river and highest in elevation being the most ancient, and those which are close to the river, which have undergone but little erosion, being the most modern of our surface formations. Examples of erosion of the Philadelphia gravel may be well seen on the Philadelphia and West Chester Railroad, which crosses a number of creeks and runs nearly parallel to the terrace for several miles. As each creek is approached the drift disappears and rocks come to the surface. So, on the Schuylkill, no gravel is seen on the river drive in the East Park, but, upon going back from the river and rising 100 feet above it, as far as the East Park Reservoir, gravel appears abundantly. Yet, on the same river, nearer the Delaware, a newer gravel, made of different materials, not only forms its banks but underlies it.

RECENT ALLUVIUM.

The most recent of all the surface deposits is the stiff bluish clay which covers the low ground in the southern part of the city. The Richmond meadows and the flats of Moyamensing, Greenwich and Tinicum are covered by this deposit. It is bounded by a low terrace, which is from 10 to 15 feet above tide. This terrace, up to which the river often comes in times of flood, crosses South Broad street diagonally below Moyamensing avenue, and, crossing the Delaware extension of the Pennsylvania Railroad, near Penrose Ferry road, winds around Point Breeze Park back towards the Gas Works, and, passing below Suffolk Park, crosses into Delaware county. Sometimes, as in Tinicum, certain islands of older gravel, rise out of the mud-flats. The blue clay of this formation is too stiff to be useful for brickmaking. Blackened fragments of twigs, roots and leaves are frequent in it, and it is said that trunks of the white cedar abound in it in some places. There is here an indication that these beds are sinking and that, as on the Atlantic coast, the water is encroaching. Frequently a good peat covers the clay. Artesian well records show that this blue mud at Frankford is 24 feet deep. Generally it is much shallower, and is underlaid by a sand, the formation next older.

THE TRENTON GRAVEL.

A light sand and gravel, free from clay, underlies the blue clay just mentioned, and extends considerably farther back from the river. It is composed principally of a sharp micaceous sand, which, when below water-level, becomes a "quicksand." Gravel lies below the sand. Unlike all the other gravels, it contains but few pebbles of white quartz, and is of a dark gray color. Its pebbles are made exclusively of the rocks forming the upper valley of the river. Their shape is also very characteristic. The pebbles of the older gravels are oval or egg-shaped, but these are for the most part flat. This flat shape is characteristic of all true river gravels. At several places along the Delaware, gold has been obtained from this gravel. The absence of clay in any of its layers indicates the action of swiftly running water. Data obtained from artesian wells have shown that this formation has a depth on Delaware avenue of about 50 feet, and that it extends up to about Third and Market streets. On Smith's Island and on the bar in the river opposite Cooper's Point it is 100 feet deep, lying upon rock. It therefore underlies the river, filling up its ancient channel. On Richmond street some very large boulders are seen lying upon the sand. Bridesburg and the Lazaretto are built upon it, the latter formerly an island surrounded by bog clay. The sand is used for building purposes. It is bounded by a terrace, which rises some 25 feet above mean tide, and is capped by the red gravel and brick clay about to be described, while rocks are frequently exposed at its base. The Chester branch of the Reading Railroad lies below this terrace, and the present line of the Philadelphia, Wilmington and Baltimore Railroad is above it. This sandy river gravel forms islands in the blue mud. It forms a level plain, and lies in a channel-cut, the older formations to rock. It evidently formed the ancient river bed.

This last and newest of all the gravels is one which at Philadelphia seems to be of little importance. It lies close along the river, and, rising a few feet above it, extends but a short distance back from the river bank. Yet, from its great development farther up the river, and more especially from the fact that in this formation, and in this formation only, have traces of ancient man been discovered, it acquires great interest, and we are tempted to inquire more fully into its boundaries, its age and its origin.

On tracing this gravel up the river, it is found that, from Philadelphia to the Neshaminy Creek, its boundary is generally between the line of the Pennsylvania Railroad and the Delaware. From this point the bounding terrace trends directly towards Morrisville and away from the present river. Thus, at Bristol, the gravel and its overlying sand extends two miles back from the river, and is bounded by a well-marked hill, upon which lie older gravels and brick-clays. These and the Tertiary gravels extend nearly seven miles inland. At Tullytown our formation extends two and a-half miles back, and at the canal shows the following succession of strata: (1) sandy loam, 1 foot; (2) fine gray "moulding-sand," 2½ feet; (3) sharp "bar-sand," 1 foot; (4) clean gray river gravel of unknown depth. In other openings near here the gravel is so full of boulders that these are dug in large quantities and sent to Philadelphia for "cobble-stones." Near Wheatsheaf Station, close to the railroad, an opening which has exposed a section of the gravel nearly half a mile in length, exhibits well the general features of the formation. The pebbles, of characteristic shape and color, are made of gray Triassic argillite, slate, red shale, sandstone, conglomerate, and various other rocks found farther up the valley, while large and often sharp boulders of red shale and other materials frequently occur. The whole formation has a very fresh appearance when compared with older gravels. Near Turkey Hill a large smooth boulder, five feet in diameter, lies upon the sand.

Upon reaching Trenton, we find an immense outspread of the gravel, and numerous fine exposures of it, both on the river bank and in the long cuts made by the Pennsylvania Railroad. The formation may therefore be designated for convenience the "*Trenton Gravel.*"

Trenton is in a position where naturally the largest amount of a river gravel would be deposited, and where its best exposures would be exhibited. It is at the point where a long, narrow valley with precipitous banks and continuous downward slope, opens out into a wide alluvial plain at a lower level. It is here that the rocky floor of the river suddenly descends to ocean level and even sinks below it, forming the limit of tidewater. Thus any drift material which the flooded river swept down in its channel would here, upon meeting tidewater, be in great part deposited. Large boulders which had been rolled down the inclined floor of the upper valley would here stop in their course, and all be heaped up with the coarser gravel by the more slowly flowing water except such few as cakes of floating ice could carry oceanward. On the other hand the finer gravel and sand would be deposited farther down the river.

This is precisely what occurs at Trenton. The material, which at Philadelphia is generally fine, grows coarser as the river is ascended, until at Trenton we find often immense boulders imbedded at all angles in the gravel. Moreover, the river has here cut entirely through the gravel down to the rock, exposing at one place a cliff of gravel 50 feet high. At Philadelphia, on the other hand, as we have seen, the river still flows on the top of the gravel. This fact may also be accounted for. Having heaped up a mass of detritus in the old river channel as an obstruction at the mouth of the gorge, the river, so soon as its volume diminished, would immediately begin wearing away a new channel for itself down to ocean level. This would be readily accomplished through the loose material, and would be stopped only when rock was reached. On the other hand, that gravel which had been deposited at places farther down the river where its bottom was below ocean level, would remain un-eroded or nearly so. When the river had attained the level of the ocean there would be no occasion to cut a deep channel, and it would therefore flow on top of the gravel which it had deposited.

The fact of the river having cut through the gravel at Trenton, while at Philadelphia it flows upon it, is due to the configuration of the rock floor of the river, which at Trenton rises above ocean level, and at Philadelphia lies nearly 100 feet below it.

At the time of the flood which deposited the Trenton gravel, the lower part of Philadelphia, the whole of Bristol and Tullytown, and almost all of Trenton were submerged. That the climate was then cold is indicated not only by the suggestion that there were then probably very large masses of boulder-bearing ice floating in the river, but also by the fact that, as stated by Dr. C. C. Abbott, bones of Arctic animals (walrus, reindeer, mastodon), often rounded by attrition, have been found in this gravel. The boulders resting upon the sand overlying the gravel suggests the grounding of large ice-cakes derived from some mass of ice large enough to be called a glacier.

It is difficult to imagine an origin for such a flood as we have described other than the melting of a glacier. This flood was not an inroad from the sea, but it came down the valley. Terraces of the same gravel may be traced above Trenton up the valley of the Delaware into the glaciated region above Belvidere. At Stroudsburg it is probably the same gravel which forms the well-marked terraces about the town, and there is every proof that the age of this formation is that immediately following the final retreat of the great glacier.

THE PHILADELPHIA BRICK CLAY.

The built-up portion of the city stands upon an extensive deposit of brick clay and gravel, sections of which are exposed in every cutting. The brick clay invariably overlies the gravel, and will therefore be first described. By far the finest exposures of brick clay are those on either side of Long lane, in the "Neck." The clay here is very compact, free from sand and gravel, and is often 15 feet or more in depth. Loam lies above it, and is mixed with it for brick-making. Well-rounded boulders of Potsdam, Medina, Trias, etc., are frequent. The whole lies upon some 20 feet of stratified gravel. It is a much finer and deeper clay than that of the northern part of the city, as at Nicetown. It is interesting to note that while the clay which is farthest from the Upland Terrace and lowest in elevation is purest and deepest, on the other hand that near the terrace, and more than 100 feet above the river, is both shallow and sandy. It suggests that the former was deposited in deep water and the latter near the shore. At the base of the terrace the clay is but two or three feet deep. The boulders of the Nicetown clay are similar to those of the Neck clay, except in the fact that in the latter there are numerous rounded and sharp fragments of triassic red shale, while in the former boulders of that material are very scarce. The boulders of both clays are invariably derived from a northern source. No shells or organic remains have as yet been noticed in this formation, and it is therefore inferred both that the water was fresh and that it had a temperature too low to support life.

In the collection of boulders from this clay made by Mr. Eli K. Price, and deposited in the University grounds, many of the rocks which occur along the Delaware from Trenton to beyond the Water Gap are represented. Some of them are derived from the Terminal Moraine. The lecturer has been able to trace almost all of them to their source. He has also traced the boundaries of this boulder bearing clay up to the glaciated region, and finds that it uniformly rises to a fixed limit of 150 to 180 feet above the river. Where the valley is wide, as at Philadelphia and Trenton, the clay is pure and fit for brick-making, but in narrow and steep portions of the valley the current has been too swift for the deposition of clay and it is represented by occasional, stranded, waterworn boulders. This clay rests against the upland terrace from Trenton to Philadelphia, at an elevation of 150 feet. On the Lehigh river, a tributary of the upper Delaware, where the bed of the river is more than 200 feet higher than at Philadelphia, the clay rises 180 feet above the river. That this was an epoch of submergence is indicated by the elevation of the deposit. While the underlying gravel was deposited by a rushing flood, it was not until quieter conditions had prevailed that clay could be formed. It is probable that this clay may be assigned to a period when the land stood 150 feet or more below its present level, and when the cold waters from the melting glacier bore ice rafts which dropped their boulders.

These boulders are often of large size. Thus in Philadelphia there are smooth boulders of Silurian rocks between 4 and 5 feet long, at an altitude of a 100 feet above the river; and on the Lehigh above the Gap, we have found a boulder six feet long, elevated 150 feet above the river at that place. In the vicinity of Bethlehem, thirty miles below the Terminal Moraine, the boulders in the clay sometimes show glacial striæ. It hardly admits of doubt that these boulders were borne by large cakes of floating ice derived from the base of the melting glacier. Finally, it is of interest to find that the clay which cements the unstratified "*till*," the "ground Moraine" which covers the glaciated region to the north, is of a character so similar to the Philadelphia brick clay, that there is a strong probability that the latter was derived, in great part, directly from the grinding base of the glacier. The Philadelphia brick clay becomes more and more stony as we proceed northward, until in valleys at the base of the Terminal Moraine of the glacier its stones are almost as numerous as those of the true glacial till. Deposits of this boulder-bearing brick clay have more than once been confounded with glacial moraines. The latter, however, as is well known, may be distinguished by the abundance of angular and ice-scratched boulders and by the absence of stratification.

THE RED GRAVEL.

Beneath the clay, and often unconformable with it, is the Philadelphia red gravel. It is a clayey gravel which packs well and is much used on roads, and whose red color is caused by the ferruginous clay in which the pebbles are imbedded. The pebbles are composed of all kinds of rock and are not flattened as are those in the river gravel. The predominant material is white quartz, but pebbles of all other materials, as conglomerate, sandstone, fossiliferous hornstone, flint, red shale, etc., are numerous. Stratification is observed in almost every section exposed. Good sections of gravel are seen near the University of Pennsylvania. It has here an elevation of about 50 feet, and comes to the surface of the ground with but a very slight covering of clay.

The clay almost always lies in the form of crests and hollows upon the gravel. Beautiful examples of wave motion may be seen at Twenty-eighth Street and Columbia Avenue, at Tenth and Tioga, at Fifteenth and Clearfield Streets, in Fairmount Park, at the Penna. Railroad cuttings near Belmont Avenue, and in many other places. In each of these we have apparently the action of a rushing flood of water upon the gravel. Often the clay lies in a kind of pot-hole in the gravel, and a concentric structure of clay and pebbles can be seen. At Twenty-eighth Street and Columbia Avenue six well-marked waves of gravel and clay may be seen, the clay always filling the hollows between the crests of gravel. Along the line of contact between clay and gravel there are alternate streaks of fine and coarse gravel.

A very beautiful example of water action is exposed at Fifteenth and Clearfield Streets, in a cut about one hundred feet in length.

Another point to be noticed in the section near the University is the stratification of the gravel, and its division into layers of three different colors,—red, black and yellow. It is instructive to note that this division is by no means a local one, but exists along a line of about equal elevation (60 to 80 feet above ocean level), in widely separated parts of the city. While the colors are of course due simply to different states of oxidation of the iron, the fact that they mark continuous deposits through long distances, indicates a uniformity in the condition of deposition which could be due only to the presence of a large body of water.

The gravel rests, not upon a hard floor of rock, as is usual with the drift in more northern States, but upon a completely decomposed gneiss. This is universally the case in every section examined in the vicinity of Philadelphia.

The lower part of the gravel often consists of a sharp, stratified, micaceous sand, made up of the materials of the decomposed gneiss. Exposures in the East Park and along the line of the North Pennsylvania Railroad illustrate this fact. It is evident, therefore, that the gneiss was decomposed before the deposition of the gravel, and that water, not ice, was the agent of that deposition. The idea that a glacier once overrode the site of Philadelphia and deposited gravels and boulders has recently been urged by a Philadelphia geologist* but is not sustained by the observed facts. In fact there is no trace of glacial action in Pennsylvania, anywhere south of the terminal moraine, notwithstanding all statements to the contrary hitherto made by other geologists.

The red gravel was deposited by a flood of the ancient Delaware, at a time when it flowed at a level over 100 feet higher than at present. It is closely of the same age as the brick clay, both having been formed during or at the close of the glacial epoch. Many facts go to prove that the red gravel and the brick clay were formed at the time when the glacier began to retreat from its terminal moraine, the ground being then depressed about 180 feet, while the Trenton gravel, which flows in a channel cut through these deposits was formed long afterwards when the last lingering remnants of the glacier were thawed out, and when the land had risen to about its present elevation.†

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*Mr. Hall, (Proc. Amer. Philos. Soc.) who concludes "that this belt of drift deposit is no other than a glacial moraine formed by the Schuylkill glacier receding from the site of the city."

† A map was here exhibited of the boundaries of the surface formations of Philadelphia, as traced out by Professor Lewis. He showed that these formations were confined to the river valley, being bounded by the "Upland terrace," and that they appeared on both sides of the river. He showed also that during part of the Glacial Epoch the Schuylkill emptied into the

THE YELLOW GRAVEL.

Nearly the whole of Southern New Jersey and a small adjoining portion of Pennsylvania are covered by a deposit of yellow gravel which has been variously known as quaternary, southern drift, etc. It extends southward all along the Atlantic coast in the region of tide water, rising some two hundred feet above the level of the ocean. It caps the watershed between the Atlantic and the Delaware (elevation 190 feet), and is well exposed in the railroad cuts at Glassboro and other places in New Jersey. This gravel, unlike those so far described, is not confined to the Delaware valley, but occurs all along the Atlantic seaboard in the Southern States. It is therefore of oceanic origin.

It is characterized by small water-worn pebbles, somewhat egg-shaped in form, seldom above an inch in length, usually less, and composed of quartz or quartzite rocks. There are also occasional pebbles of flint, and of fossiliferous hornstone and chert. It contains no large boulders, and has no pebbles of soft or readily decomposable rocks, and its pebbles have nearly all a weather-worn eaten appearance. Still other circumstances, such as the great amount of erosion it has suffered, and the decomposed state of the beds upon which it lies, point to the conclusion that it is an ancient deposit of marine origin, made during a submergence in preglacial times. The glacial drift overlies and is more recent than this yellow gravel. This gravel is of a yellowish color, becoming white when exposed to the weather, and is more sandy than the red gravel. For these reasons it is less esteemed for road making. The Germantown railroad cuts through this gravel at New York junction. The speaker has found here pebbles containing cyathophylloid corals, favosites, a trilobite, etc. The connecting railroad at Ridge avenue station cuts through the same gravel, and here occur *strophomena*, etc. Other fossils have been found below the clay in the East Park and at the Centennial Grounds. Pebbles of triassic red shale, so common in the red gravel, do not occur in this older yellow gravel.

The yellow gravel, which can always be recognized by the fossiliferous pebbles of Niagara limestone, etc., in it, may be studied on Darby

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Delaware at the Falls of Schuylkill, and that the State house steeple would then have been completely submerged. He spoke of the gold, which, in small quantity, disseminated throughout the clay, stating that it has been estimated that $126,000,000 of gold lies underneath the paved part of the city, and many times more within its corporate limits. He also described the process of brick making.

road, near the horse car depot, in the railroad cut at Ridley Park, Delaware county, where corals and other fossils abound, and in many other places in and about the city. It generally occurs near the base of the upland terrace upon a plateau covered by more recent brick clay. It is from this oceanic gravel that most of the pebbles of the red gravel have been derived. The yellow gravel is probably of *newer Pliocene* age.

THE BRYN MAWR GRAVEL.

Upon the summits of some of the highest hills in the gneissic region back of Philadelphia, at a mean distance of about nine miles from the river, and at elevations of from 325 to 450 feet above it, there are isolated patches of an ancient gravel, different from any yet described, to which the speaker has given the provisional name of "The Bryn Mawr Gravel." It can always be recognized by the presence of sharp or partially rounded fragments of a hard, heavy iron sandstone or conglomerate. Such fragments are often covered by a brownish black iron glaze. More than fifteen years ago, the speaker noticed in the soil of the upper part of Germantown, pieces of this conglomerate, unlike any known rock, and it is only of late that its origin has been suspected. It consists of well-rounded pebbles of quartzite or siliceous sandstone cemented by iron into a stone which is often very hard. This conglomerate is found in occasional fragments upon ground over 300 feet high, but is not found in abundance until an elevation of over 400 feet is reached. At these highest points it occurs in a red gravel whose pebbles are identical with those of the conglomerate.

One of such points is near Chestnut Hill, on the city line road at its highest elevation, near Willow Grove road. Here, nearly nine miles from the river and 425 feet above it, is a patch of this gravel and conglomerate, in which sharp fragments of quartzite are numerous, but there are no traces either of triassic red shale, of fossiliferous pebbles, or of rounded pebbles of the underlying gneiss.

A similar tract of this gravel occurs at Bryn Mawr, extending from that place to near Cooperstown. A good section is exposed in the railroad cut below the station. From this locality the formation is named. It is here about 430 feet high, and nine miles from the river. The gravel is ten feet deep, and lies upon a steeply-dipping gneiss so completely decomposed that it is as soft as clay. Here, as at Chestnut Hill, the gravel lies in an isolated patch upon a hill, distant from any stream or other eroding agency. The gravel holds sharp fragments of primal rocks, and also the iron conglomerate. As at Germantown, the fields below, to the south, contain occasional fragments of the conglomerate.

Another good exposure of the Bryn Mawr gravel is on a hill crossed by the road leading from Haverford College to Cooperstown. The conglomerate is here in large, sharp fragments, and the gravel shows slight horizontal stratification. On the crest of the hill, some 450 feet high, there is a weather-worn boulder, four feet in diameter, of a soft, coarse, brown sandstone of Bryn Mawr age, apparently in place.

A fourth, precisely similar exposure of gravel with conglomerate, and at about the same elevation, caps the hill back of Media, near the Rosetree.

Without describing any further exposures, it already appears that in these elevated patches of ancient gravel we have the last remnants of a once continuous formation. The very great erosion which has swept away all but these few traces is a sufficient proof of its age. There are no points at all approaching the elevation of these hills, between them and the Atlantic Ocean; and it is at once suggested that these patches are the remnants of an oceanic deposit, possibly of Tertiary age. It is interesting to find that a precisely similar formation caps some of the hills in New Jersey. On top of the hill at Mount Holly, N. J., is an identical conglomerate and gravel, similar in appearance, and composed of the same materials as the formation in Pennsylvania. The conglomerate has the peculiar ferruginous glaze already noticed. It here overlies cretaceous marls and sands.

The Bryn Mawr gravel caps numerous high hills in Delaware county, and in northern Delaware increases largely in extent, covering the gneiss hills in patches several miles in length. At a point two miles northeast of Wilmington it comes within a mile of the river. It is in many places five feet deep and is less eroded than in Pennsylvania. As in Pennsylvania, its pebbles are mostly of sandstone and quartzite, and fragments of iron conglomerate are abundant. A similar formation occurs upon the heights of Georgetown, D. C., and continues through the southern States in the same relative position. It is probably of Tertiary age, and represents the outliers of portions of the gravelly shore line of certain oceanic deposits which, nearer the Atlantic, are more largely developed, but represented by clays, sands, and such other finer material as would be deposited farther from shore.

This region has been elevated over 400 feet since these deposits were laid down, a fact which may lead to a more precise estimate of their antiquity.

Recapitulating the various surface formations here distinguished as occurring at Philadelphia we have, beginning with the most recent:

Formation.	*Geological Age.*
Recent alluvium.	Modern.
Trenton gravel.	Post-glacial.
Philadelphia brick clay.	Glacial.
Red gravel.	Glacial.
Yellow gravel.	Pre-glacial.
Bryn Mawr gravel.	Tertiary.

In these six deposits is written the ancient history of the Delaware valley. If we read the record aright, they tell us that, long ago, before man was created, when strange mammals roamed abroad, and when all southern New Jersey lay deep beneath the Atlantic, the waves of the ocean broke upon the hills of Bryn Mawr, Chestnut Hill and Media. At the same time, an inlet from the sea extended over a great part of the Montgomery county limestone valley, depositing clays holding extensive beds of iron ore. This region, then 450 feet lower than now, was afterwards slowly upheaved, and as the waters retreated, the yellow gravel was probably formed. Afterwards, and perhaps in consequence of this rise, the climate grew colder, and glaciers crept down from Greenland and Labrador, forming a huge *mer-de-glace* thousands of feet in thickness, which advanced to within 60 miles of Philadelphia. Again the land descended 175 feet lower than it now is, and again the waters covered the city. This time it was fresh water of icy coldness, bearing great icebergs, which stranded on the shores formed by the hill at Wayne Junction, Belmont, George's Hill, Hestonville, Haddington and Swarthmore. At this time the river Delaware was 10 miles or more in width, nearly 200 feet deep, and, as a roaring flood, deposited the red gravel and left in it the records of its waves. As the flood became more quiet, though still filled with mud derived from the base of the glacier, the brick clays were laid down, the floating ice floes meanwhile dropping their far carried boulders all over our city.

After many thousands of years, the "Great Ice Age" at length came to a close, the land rose to about its present level or somewhat higher, the waters retreated, and finally, as sudden elevations of temperature thawed the glaciers still remaining in the head waters of the Delaware, there came those last great floods which deposited the "Trenton gravel." The Delaware, then so wide as to submerge most of Trenton, all of Bristol, and the river front of Philadelphia nearly up to the State house, was again filled with floating icebergs. The walrus played in its waters, while the reindeer and the mastodon roamed on its banks. Man also then first appeared. With habits most probably like those of the Esquimaux, living in most primitive ways, he hunted and fished on the banks of the swollen Delaware, and occasionally dropped into the water his rude stone implements, long afterward to be found to tell the story of their makers.

Finally, the land began the sinking which is now in progress, the climate grew warmer, the Red Indian was introduced, and the modern era began.

This, in brief, is the tale told by our clays and gravels, Surely the long despised cobble-stones of our ill-paved streets become more worthy of our respect when we know their story. Still more interesting do they become when we learn that they can tell us of the early history of our own race. They belong to the "Trenton gravel," and we have already spoken of the relation of that formation to the *Antiquity of Man* on the Delaware. It now remains to point out more exactly what that relation is.

Some years ago, Dr. C. C. Abbott, of Trenton, announced his discovery in this gravel of stone implements of human workmanship, distinct in shape and characters from those of the modern Red Indian. They are larger and more rude than modern implements, being roughly chipped and never ground to an edge or polished. Unlike modern arrowheads and spearheads, which are generally made from quartz, flint or some hard sandstone, these are all made of gray argillite, a rock which is found in places farther up the river, and which is a Triassic shale altered and hardened by the heat from adjacent trap dykes.

They are essentially of *palaeolithic* type, and have identical characters with the river drift implements found in the valleys of France, England, and other parts of Europe. Dr. Abbott states that the modern implements ("neoliths") are confined to the surface of the ground or a few inches below, but are never associated with the "palaeoliths" lower down, which may occur at depths of ten feet or more below the surface. When found below the surface, these palaeolithic implements always occur in the Trenton gravel, and never in the older gravels, and this fact alone offers strong evidence that they belong to and are of coeval deposition with that formation. In going over the ground in company with Dr. Abbott, it was interesting to find that it was only within the limits of the Trenton gravel, as previously traced out and mapped by the lecturer, that these implements had been found below the surface. Many competent archæologists sustain Dr. Abbott in believing that these rude implements are a constituent part of the gravel, and are neither natural forms nor intrusive objects.

All the evidence that has been gathered points to the conclusion that at the time of the Trenton gravel flood, man in a rude state lived upon the banks of the ancient Delaware. He may have been in the habit of spearing fish and seals with spears pointed by his rough stone implements, and these having been dropped into the flood may have sunk into the loose and shifting gravel. The climate was cold and the flooded river was filled with icebergs. A similar period in Europe has been called the *Reindeer Period.*

It is interesting to find, as pointed out by archæologists, that until lately the Esquimaux have used rude stone implements similar in appearance to those found in the Trenton and other river gravels, and it has been suggested that that race, now living in a climate and under conditions perhaps similar to those once existing on the Delaware, may have some kinship with the pre-Indian people of this river. It may be that an Esquimaux race, living here at the time of the flooded Delaware, were driven north by the coming of the Red Indians.

Whether or not these ancient people were the ancestors of our present Indians, it is of interest to find their great antiquity, as shown by the Trenton gravel. As already stated, that gravel was deposited at the close of the last glacial epoch. The conditions at that time have already been described, and in the last lecture an attempt was made to calculate the probable date of that period. A careful search among the more recent gravels underlying Philadelphia, might throw more light upon this yet unsettled problem.*

Coming now to the second portion of our subject, being a description of the *rocks* in the vicinity of the city, time forbids more than a cursory examination.

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*At the opening of the lecture, Mr. John Sartain brought for examination a supposed Indian implement found by him in gravel, 24 feet below the surface of the street, in an excavation below the cellar of No. 728 Sansom street, Philadelphia. This implement has since been described in full by Prof. Lewis, in the Proceedings of the Academy of Natural Sciences, Feb. 6, 1883.

THE PHILADELPHIA GNEISS.

The above described superficial formations rest upon an ancient metamorphic rock, composed of quartz, felspar, and mica, arranged in layers, and known as *gneiss*, and thus frequently in the same street cutting a section may be exposed of one of the most recent deposits lying directly upon one of the most ancient geological formations known. The age of the glacier is as nothing in comparison with that of the gneiss. The latter forms the old foundation stones of the continent, from which all the other rocks were afterwards formed. The flakes of mica in the sandstones of the coal strata and in the brownstone used for our houses, are derived from this ancient formation of gneiss, which has been the bed of many an ocean. Underlying all the other rocks of the globe, the *Archaean* rocks were made at the time when the lowest forms of life were introduced. Of the archaean rocks, the oldest are the *Laurentian,* to which the gneiss near Conshohocken probably belongs, and the newer are known as *Huronian.* To this division belongs the gneiss at Philadelphia, which is identical with the gneiss which forms the White Mountains of Vermont and the Rocky Mountains of Colorado. From the former locality it is sometimes called *Mont-Alban.* These ancient rocks are always greatly twisted and contorted, generally dipping at high angles to the horizon, as may be seen along the Schuylkill in the East Park.

As the earth contracted during its cooling from the molten state, its crust shrivelled and became wrinkled like the skin of a dried apple. The strata were tilted up to form mountain chains, which were afterwards ground down by long continued erosion. No life could exist until the earth had cooled down to 200° F. Some idea of the length of time before that stage is given in Helmholz's calculation, based upon the rate of cooling of lavas, that for the earth to cool from 2,000° to 200° F., would have required three hundred and fifty millions of years. Any life that may have existed in the Philadelphia gneiss has been obliterated by the heat, pressure, contortions, and consequent metamorphism to which it has been subjected. These same forces, however, have made our rocks so full of interesting minerals. Minerals and fossils, therefore, rarely occur together.*

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* The principal minerals in the Philadelphia gneiss were given, and the boundaries of the formation were shown upon a map. It was stated that no accurate geological map of this region had yet been constructed.

The beds of serpentine which occur in the gneiss of the northern part of the city, are regarded as the result of the alteration of gneissic rocks by contact with magnesian waters.

THE PRIMAL SLATES AND POTSDAM SANDSTONE.

On top of the gneiss and at the base of that great group of fossiliferous rocks known as the Palaeozoic system, is a peculiar formation in the middle strata of which occur the oldest fossils yet found in the vicinity of Philadelphia. The lower part of the formation is the pale sandy slate which forms Edge Hill and Barren Hill, and the northern base of Chestnut Hill. The slates are closely folded and stand often almost perpendicular. At Edge Hill station on the N. P. R. R., the strata are broken and bent over by the action of gravity draging them down hill—this phenomenon being known as "creep." These slates (known as hydro-mica slates) are probably of the same age as the diamond bearing slates of Brazil and elsewhere.

A sandstone, which from its great development at Potsdam, N. Y.' has been named from that place, overlies the slates and often contains long tubular fossils, known as *Scolithus linearis,* which appear to be the casts of worm-holes. As shown by the ripplemarks, this sandstone was formed at the edge of an ancient sea. Marine worms burrowed in the sea beach and the winds drifted the sands, which ages afterwards were hardened and tilted up to form the rocks at Willow Grove, and those along the north side of Chester valley.

On top of this fosiliferous sandstone is a series of soft, iron-bearing shales, often decomposed into variegated clays, carrying extensive beds of iron ore (limonite). Crossing the limestone valley, diagonally, in a series of anticlinal rolls, which rise through the overlying limestone, this formation supplies a large amount of iron ores to our blast furnaces.

THE AURORAL LIMESTONE.

The bluish-white streaked marble which adorns the door steps and window sills of the greater part of our houses comes from the limestone valley which, on either side of the Schuylkill, lies immediately north of the city. Originally formed by the accumulation of minute organic remains under deep sea water, subsequent changes have obliterated all traces of animal life, the streaks of carbonaceous material and the occasional specks of graphite alone remaining as witnesses. These same changes have altered certain strata of the limestone to the crystalline state known as marble. The quarries at Marble Hall are well worthy of a visit. Farther inland, in places removed from the disturbing influences of the Philadelphia region, the same limestone is filled with fossil shells and corals. Professor Rogers called it the "Auroral" limestone because it was the dawning of the long geologic day of the succession of Palaeozoic life.

Like almost all limestones, the Auroral limestone always occurs in a valley. These valleys, such as that north of Chesthut Hill, are such from the fact that the limestone for countless ages has been constantly dissolved away by the power of rain-water, and the surface lowered by the breaking down of underground caverns. On the other hand, the Kittatinny mountain is a mountain, not because its rocks are more tilted up than other rocks, but simply because the hard sandstone which forms it has resisted these atmospheric and erosive agencies, while the country on either side of it has been lowered.

The *iron ore*, so common in the valley north of Chestnut Hill, most of which is in the form of *limonite*, has been derived by solution and subsequent segregation from the older underlying shales, some of it having been altered in place from these shales, some of it belonging to clays of tertiary age, and some of it having been drifted still more recently and made a surface deposit. The lecturer several years ago discovered *lignite*, or brown coal, at some localities in the vicinity of Marble Hall. It had the form of twigs and branches, and, associated with kaolin, potter's clay and iron ore, threw light upon the age of these deposits.

THE TRIASSIC SANDSTONE.

A succession of red sandstone and shales, which, from its threefold division in Germany has been called the Trias, and which belongs to Mezozoic time, being more recent than the coal measures and older than the New Jersey marl, forms in Pennsylvania a belt, the lower edge of which extends from Trenton to Norristown and Valley Forge, whence it traverses Berks, Lancaster, York and Adams counties, entering Maryland south of Gettysburg. The strata all dip at a low angle northwestward, and appear to have been deposited in a shallow estuary or inland sea which once occupied this region. As shown by the composition of its pebbles, this Triassic sea washed the shores of the Philadelphia mountains.

This was the age of reptiles. Labyrinthodonts waded in the mud-flats and left their tracks preserved to this day. Some of them walked altogether on their hind legs like a kangaroo, looking probably like a long-legged frog covered with scales, with teeth several inches long, and tall enough sometimes to look over a twelve-foot wall. Other creatures, called Dinosaurs, were like four-legged birds, the hind feet being bird-like. One of these, which had teeth like a crocodile, lived at Phœnixville, where its bones have been found. The footprints of these creatures, the mud cracks and ripple marks and rain prints, the cycads and tree ferns, and the occasional seaweeds, all tell the story of this formation and give fresh interest to that part of it which, under the name of "brownstone," is used for the fronts of our Walnut street houses.

As the Triassic age drew to a close, there was an outburst of volcanic action. Streams of molten lava issued from the earth to form the trap dykes which are crossed by the Reading Railroad at Conshohocken, by the North Pennsylvania Railroad near Quakertown, and by the Pennsylvania Railroad twenty miles before reaching Harrisburg.

The sketch here given of the geology of Philadelphia is but a fragment of what may be learned at our very doors. The gneiss of which our cellars are built takes us back in thought to that remote time when the earth had just cooled sufficiently to permit the introduction of the lowest forms of life; the marble of our door-steps tells of an ocean inhabited by no fishes, which washed land upon which grew no trees; our brownstone fronts recall an age of strange reptiles and uncouth birds, when seaweeds grew on the hills back of Norristown, and when earthquakes cleft open the earth; the bricks of our walls teach us of an epoch when the city was under water, the Schuylkill joined the Delaware at the Falls, and icebergs floated down from the great glacier farther north; and the cobble-stones, finally, mutely speak of that age of cold, preceding our own, when the glaciers melted and retreated, and when, on the banks of the flooded Delaware primeval MAN first appeared.